I claim:

1. A data network comprising

a source that transmits data messages to a plurality of receivers forming a multicast group of receivers, and wherein each of the receivers comprises

first apparatus that receives a transmitted data packet and accumulates statistics relating to the transmission of data packets from the source to the receiver, and

second apparatus that generates a congestion control value and sends the value to the source, and wherein the source adjusts its transmission of data packets to the receivers as a function of a selected one or more of a plurality of congestion control values that it receives from respective ones of the receivers.

2. The data network of claim 1 wherein the receivers forming the multicast group also form a multilevel hierarchical reporting network that forwards a congestion control value to the source and wherein a receiver positioned at an intermediate level in the reporting hierarchy includes apparatus that generates a consolidated congestion control value as a function of a combination of the congestion control value that it locally generates and each consolidated congestion control value that it receives from receivers positioned at a preceding level in the hierarchy and then forwards the consolidated congestion control value to the source via the next succeeding level in the reporting network.

3. The data network of claim 2 wherein the source is positioned at the highest level in the reporting hierarchy.

4. The data network of claim 1 wherein each of the receivers uses a window based scheme to determine a maximum expected sequence number as its respective congestion control value, and wherein the source uses the minimum of the congestion control values that it respectively receives from the

receivers as a maximum sequence number of a next packet that the source transmits to the receivers.

5. The data network of claim 1 wherein each of the receivers uses a window based scheme to determine, as a function of an updated widow size, maximum sequence number of packets contiguously received, total length of received packets that are not contiguous and size of an associated reassembly buffer a maximum expected sequence number as its respective congestion control value, and wherein the source uses the minimum of the congestion control values that it respectively receives from the receivers as a maximum sequence number of a next packet that the source transmits to the receivers.

6. The data network of claim 4 wherein the second apparatus includes apparatus that determines a transmission window as a function of loss and delay measured by the respective receiver, and generates the respective congestion control value as a function of (a) the determined transmission window and (b) sequence number of the last data packet received successfully in sequence with prior received data packets.

7. The data network of claim 4 wherein the second apparatus includes apparatus that determines a transmission window as a function of loss and delay measured by the respective receiver and generates its respective congestion control value as (a) a function of the determined transmission window, (b) sequence number of a last data packet received successfully in sequence with prior received data packets and (c) number of data packets received out of sequence.

8. The data network of claim 4 wherein each receiver includes a buffer for storing received data messages and wherein the second apparatus includes apparatus that determines a transmission window as a function of loss and delay measured by the respective receiver and generates its respective congestion control value as (a) a function of the sequence number of a last data packet received successfully in sequence with prior received data packets and minimum

of (b1) the transmission window plus the number of data packets received out of sequence, or (b2) the number of memory locations in the re-assembly buffer available for the storage of out-of-sequence data packets.

9. The data network of claim 3 wherein each of the receivers uses a rate based scheme to determine its respective congestion control value, and wherein the source applies the minimum of the of the congestion control values that it respectively receives from the receivers as a rate of transmission of new data packets.

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10. The data network of 1 wherein the source inserts a time stamp in a data packet that it transmits to the multicast group of receivers and wherein the first apparatus associates a received data packet with a current time stamp and wherein said first apparatus includes apparatus that determines a trip delay from the source to the receiver as a function of the difference of the inserted time stamp and a current time stamp.

11. The data network of claim 2 wherein each receiver further includes third apparatus that determines a trip delay to the source via the reporting network as a function of a (a) time stamp that it associates with a message containing a congestion control value that the receiver forwards to a receiver positioned at the next highest level in the reporting hierarchy, and (b) trip delay returned by the receiver positioned at the next highest level, in which the returned trip delay is indicative of the trip delay from the latter receiver to the source.

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12. The data network of claim 11 wherein each of the receivers forward its respective congestion control value to the source via the IP layer multicast network..

13. A data receiver comprising

first apparatus that receives a data packet from a source of data packets and accumulates particular information relating to the transmission of data packets to the receiver via a data network, and

second apparatus that generates a transmission control value as a function of the accumulated information and forwards the generated value as a feedback message to the source so that the source may control its transmission of data messages to the receiver as a function of (a) the transmission control value received from the receiver and (b) transmission control values received from other such receivers.

14. The receiver of claim 13 wherein the receiver is one of a plurality of receivers that form a multicast group within the data network.

15. The receiver of claim 14 wherein the multicast group of receivers form a multilevel hierarchical reporting network that forwards a transmission congestion control value to the source and wherein a receiver positioned at an intermediate level in the reporting hierarchy includes apparatus that generates a consolidated congestion control value as a function of a combination of the congestion control value that it generates locally and each consolidated congestion control value that it receives from receivers positioned at the preceding level in the hierarchy and then forwards the consolidated congestion control value to the source via the next succeeding level in the reporting network.

16. The receiver of claim 13 wherein the receiver uses a window based scheme to determine a maximum expected sequence number as its respective congestion control value, and wherein the source uses the minimum of the congestion control values that it receives as a maximum sequence number of a next packet that the source transmits to each said receiver.

17. The receiver of claim 15 wherein the second apparatus includes apparatus that determines a transmission window as a function of loss and delay measured by the respective receiver and generates its respective congestion

control value as a function of the determined transmission window and sequence number of the last data packet received successfully in sequence with prior received data packets.

18. The receiver of claim 15 wherein each of the receivers uses a window based scheme to determine, as a function of an updated widow size, maximum sequence number of packets contiguously received, total length of received packets that are not contiguous and size of an associated reassembly buffer a maximum expected sequence number as its respective congestion control value, and wherein the source uses the minimum of the congestion control values that it respectively receives from the receivers as a maximum sequence number of a next packet that the source transmits to the receivers.

19. The receiver of claim 15 wherein the second apparatus includes apparatus that determines a transmission window as a function of loss and delay measured by the respective receiver and generates its respective congestion control value as a (a) function of the determined transmission window, sequence number of the last data packet received successfully in sequence with prior received data packets and (b) number of data packets received out of sequence.

20. The receiver of claim 13 wherein each receiver further comprises a re-assembly buffer for storing received data packets and wherein the second apparatus includes apparatus that determines a congestion control value as a function of function of loss and delay measured by the respective receiver and generates its respective congestion control value as a (a) function of the sequence number of a last data packet received successfully in sequence with prior received data packets and minimum of (b1) the transmission window plus the number of data messages received out of sequence, and (b2) the number of memory locations in the re-assembly buffer available for the storage of out-of-sequence data packets.

21. The receiver of claim 13 wherein the receiver uses a rate based scheme to determine the congestion control value, and wherein the source

applies the minimum of the congestion control values that it receives as a rate of transmission of new data packets.

22. The receiver of claim 14 wherein the source inserts a time stamp in a data packet that it transmits to the multicast group of receivers and wherein the first apparatus associates a received data packet with a current time stamp and wherein said first apparatus includes apparatus that determines a trip delay from the source to the receiver as a function of the difference of the inserted time stamp and current time stamp.

23. The receiver of claim 14 wherein each receiver further includes third apparatus that determines a trip delay to the source via the reporting network as a function of a (a) time stamp that it associates with a message containing a congestion control value that the receiver forwards to a receiver positioned at the next highest level in the reporting hierarchy, and (b) trip delay returned by the receiver positioned at the next highest level, in which the returned trip delay is indicative of the trip delay from the latter receiver to the source.

24. A data transmitter comprising

a sequence number generator, and

a controller that (a) inserts the next generated sequence number in a data packet, (b) regulates the transmission of the data packet based on a congestion control value determined using either a rate based or window based scheme and (c) transmits the data packet in accordance with the congestion control value to a group of receivers forming a multicast group of receivers, in which the congestion control value is selected from a group of congestion control values received from individual ones of the receivers.

Abstract:

The operation of a multicast network is enhanced by shifting the responsibility for performing congestion control with regulation for the

transmission of multicast data packets from the transmitter to the receivers, such that each receiver computes a congestion control value using particular statistics that it accumulates and then forwards it congestion control value to the source/transmitter. The source then regulates its transmission of data packets in accordance with a selected one of the congestion control values that it receives. Moreover, a hierarchical reporting network may be used to convey the regulation values from the receivers to the source such that congestion control values generated by the receivers are consolidated at various layers in the hierarchical reporting network so that the source receives consolidated control values from just the receivers connected directly to the source, rather than a value from each of the receivers.